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LOANPILOT™ EU STRESS TEST MODEL LIBRARY
APPROACH AND USER MANUAL

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SUMMARY

OSIS has published a freely accessible online tool LoanCracker™ –EU Stress Test that can be found at http://www.os-is.com/asset-quality-review-stress-testing/ providing intuitive analytics of the 2014 EU-wide stress test data. Focusing on credit risk, OSIS has used the EBA data to create a library of stress test models at an unprecedented level of granularity for around 100 European banks in more than 30 countries. This document provides a brief description of the underlying methodology that we used to create the model library. The document supplements the online tool, a manual explaining the use of the tool, and a technical document regarding stress test model development and testing (all available on www.os-is.com).

In short, we back out the stressed probability of default (point-in-time). We then estimate the sensitivities to a number of macro-economic variables by means of linear regression for the PD and its probit transform for better comparison with models used for regulatory capital.

The library is useful for model benchmarking allowing the identification of outliers in a peer analysis, supports discussions with supervisors, and can be used to calibrate top down stress testing models in the absence of sufficient historical data.

1. DEFINITIONS AND FILTERS

This section lists the definitions used and briefly describes the relevant filters available in the online tool.

1.1 DEFINITIONS

DEF 1 Balance Sheet Assumption: In total, 25 banks were excluded from the static balance sheet assumptions because of restructuring plans approved by the European Commission before the 31/12/2013. These banks were allowed to be stressed under a dynamic balance sheet assumption.

DEF 2: Change in Unemployment: The calculated annual percentage change in the unemployment rate prescribed under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12.

DEF 3 Coverage Ratio – defaulted stock: The provision stock of defaulted exposures divided by the defaulted exposure amount.

DEF 4 EAD: Abbreviation used for exposure values in the EBA template. Total EAD is the aggregated total exposure for a bank, country and exposure.

DEF 5 HPI: The residential property price index prescribed under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12.

DEF 6 GDP: The gross domestic product prescribed under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12.

DEF 7 Impairment Rate: The sum of New and Old Impairment Flows divided by the total exposure value (EAD).

DEF 8 PD-PIT: The point-in-time probability of default estimated in section [2.1.1] and is available by bank, country, exposure class, scenario and period. PD-pit calculated to be negative are excluded.

DEF 9: RI: The calculated annual real interest rate calculated from the prescribed long term government bond yields minus the prescribed inflation rates under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12.

DEF 10 SLTV: The calculated stressed loan-to-value based on the indexed loan-to-value for the retail exposure secured by real estate. SLTV is available under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12 by updating LTV with HPI for all scenarios and periods (see section [2.2.1]).

DEF 11 Stock of Provisions: The sum of the provision stock on defaulted and non-defaulted exposures.

DEF 12 Unemployment: The prescribed unemployment rate under the baseline and adverse scenario for 2014/12, 2015/12 and 2016/12.

1.2 FILTERS IN THE ANALYTICAL TOOL

Balance Sheet Assumption: The filter allows excluding banks with dynamic balance sheet assumption from the analysis (see DEF 1).

Bank: Contains the relevant set of banks, primarily based on the filter “Country of Bank”.

Country of Bank: This is the unique home county of the bank as determined by EBA.

Country of Exposure: Restricts the number of countries where a bank is exposed. If you would like to see all Dutch banks in Belgium click: "Country of Bank": Netherlands, "Bank": All, "Show only Banks in": Non-Home country, "Country of Exposure": Belgium.

Credit Exposure: Shows a specific credit exposure item.

Exposure: Choose one of the particular credit exposure classes. In some cases it is only possible to select a restricted number of exposures, e.g. regressions on CLTV are only available for exposure classes that show an LTV (i.e. Retail – secured by real estate).

Highlight Bank + Exposure Country: Highlights the selected bank in a specific exposure country the workbook and provides additional information.

Macro Stress: OSIS provides five different macro variables for analysis (GDP, Unemployment, Change in Unemployment and HPI (see list of definitions)). In addition, OSIS calculates the stressed loan-to-value (SLTV) and real interest rate as explained in section 2.2.

Period: Shows a specific period in the analytical tool. For EBA Macro Stresses e.g. we have we have future period stressed macro scenarios.

Ranking: A few workbooks rank a specific metric in ascending or descending order for a certain set of banks.

Scenario: The two scenarios prescribed by EBA: the baseline scenario and the adverse scenario.

Significance Level: Set the significance level to highlight specific regression results. For example, to highlight regressions with a maximum P-value of 0.2 insert "0.2".

2. DATA / METHODOLOGY

This section briefly discusses the methodology used for some of the calculated measures utilized in the *EU-wide stress test 2014 analytics* and primary data sources.

2.1 PRIMARY DATA SOURCES

Credit risk:
http://www.eba.europa.eu/documents/10180/851794/Credit_risk.csv

Data dictionary
http://www.eba.europa.eu/documents/10180/851794/Data%20dictionary.xlsx

Metadata
http://www.eba.europa.eu/documents/10180/851794/Metadata.xlsx

Macro-economic scenarios
https://www.eba.europa.eu/documents/10180/669262/2014-04-29_ESRB_Adverse_macroeconomic_scenario_-_specification_and_results_finall_version.pdf

2.2 STRESSED MACRO FACTORS

We deduce the macro sensitivity for a particular credit exposure via backward engineering by regressing relationship per bank and credit risk exposure between the

PD-Pits or probit PD-Pits and country specific macro-stresses: GDP, HPI, unemployment and change in unemployment.

OSIS has added stressed LtV's "SLTV" to these regressions. Most of the 123 examined banks disclosed their loan to value (LTV) (as of 2013) for the credit exposure classes; Retail – secured real estate property, Retail –secured real estate property – Of Which: non-SME and Retail – secured real estate property – Of Which: SME. OSIS updated the LTV in the next year given a certain scenario in the HPI stress. Thus the SLTV in the baseline period in 2014 can be calculated as follows:

2.2.1 $$SLTV_{t,b}^{+/-} = \left(\frac{LTV_b}{1 + \frac{HPI_{t,c}^{+/-}}{100}} \right)$$

where LTV_b is the bank specific loan-to-value and $HPI_{t,c}^{+/-}$ denotes the scenario, period and country specific housing price index. In a similar fashion we can calculate the SLTVs for all years and both scenarios.

In addition OSIS has added real interest rate as a stressed macro factor versus PD-Pits. The real interest rate is scenario, period and bank specific and is calculated as follows:

2.2.2 $$RI_{t,b}^{+/-} = LTGY_{t,c}^{+/-} - \pi_{t,c}^{+/-}$$

where $LTGY_{t,c}^{+/-}$ is the scenario, period and country specific long-term government bond yield and $\pi_{t,c}^{+/-}$ denotes scenario, period and country specific inflation rate.

2.3. UNIVARIATE AND MULTIVARIATE LINEAR LEAST SQUARES REGRESSION

Several macro-economic variables have been used in our stress test analysis based on their general popularity in bank stress test models and based on explicit stress scenarios being publicly available. We use the annual percentage change in GDP (short GDP), the annual percentage change in residential property prices (HPI), the unemployment rate in levels (UE), the annual percentage change in unemployment (UE_change), for retail exposures secured by real estate only, the stressed loan to value (SLTV) based on the disclosed loan to value ratio and indexed by the country HPI and the real interest rate (short RI). In case the exposure of a particular bank is < EUR 10 million in an exposure country and credit exposure class the regression is not conducted. The macro variables are regressed on PD-Pits where the univariate least squares regression is defined as follows:

2.3.1 $$PD_Pit_t = \alpha + \beta_1 X_{1,t} + \varepsilon_t$$

where α is the intercept, β_1 denotes the sensitivity to a certain macro stress and $X_{1,t}$ denotes the macro stress. For each bank, country and exposure class combination we have six observations (2 scenarios * 3 periods) to estimate (3.3.1). Only data sets with positive PD PIT estimates are considered. The multivariate regression are based on two independent macro variables:

2.3.2 $$PD_Pit_t = \alpha + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \varepsilon_t$$

where α is the intercept, β_1 and β_2 denote the sensitivity to macro stress X_1 and X_2, respectively.

2.4 REGRESSIONS BASED ON THE PROBIT TRANSFORMATION

In probability theory and statistics, the probit function is the quantile function associated with the standard normal distribution. For instance, if the PD_Pit_t = 2.5% then the associated probit function is

2.4.1 $$\Phi^{-1}(p) = \Phi^{-1}(0.025) = -1.96$$

where Φ^{-1} is the inverse of the cumulative standard normal distribution. This result implies that a 2.5% probability of default corresponds to a z-value of -1.96 in the standard normal distribution.

The nonlinear probit transformed default rate or PD is well known from the Basel Vasicek two parameter model to estimate regulatory risk weights and capital. Using the probit transformed PD as a dependent variable has two key advantages, the analogy with the Basel capital framework and the natural restriction of the PD onto the unit interval. Linear regressions on the PD directly have the advantage of directly interpreting the regression coefficients as sensitivities whereas they do not prevent the PD to become negative or larger than one in extreme scenarios. The univariate regression with probit transformed PD then reads

2.4.2 $$\Phi^{-1}(PD_Pit_t) = \alpha + \beta X_t + \varepsilon_t$$

and similar for the multivariate probit regression

2.4.3 $$\Phi^{-1}(PD_Pit_t) = \alpha + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \varepsilon_t$$

The β-coefficient is harder to interpret, since a 1% change in the macro stress X_i, implies a $1\% * \beta_i$ change in the *z*-score of the PD-pit. Nonetheless the relative steepness of the regression line between banks is useful in comparing macro sensitivities between banks and credit exposure classes.

2.5 INFORMATION CRITERIA

It is common practice to compare information criteria between regression models to assess the goodness-of-fit while penalizing for increasing model complexity. Adding more parameters in a regression model always increases the R^2, but might cause so-called over fitting of the model. The information criteria use a penalty term for the number of parameters in the model compared to the additional information these parameters add to the model. The lower the information criteria, the better the model. We utilize two common information criteria: the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC). The AIC is defined as follows:

2.5.1 $$AIC = 2k - 2\ln(L)$$

where k is the number of parameters in the model and L is the maximized value of the likelihood function for the model. The BIC is defined as follows:

2.5.2 $$BIC = -2lnL + k(\ln(n) - \ln(2\pi))$$

where k is the number of parameters in the model, L is the maximized value of the likelihood function for the model and n denotes the number of observations.

3. EBA MACRO STRESSES

This workbook in the online tool is the starting point of this analysis. There are three filters, which can be used to view a particular macro-stress in a particular scenario, period and for a specific bank. The severity of these macro stresses are

visualized by colors in a map of Europe. Figure 1 illustrates the GDP stress in 2016 in the adverse scenario for the Deutsche Bank in all exposure countries.

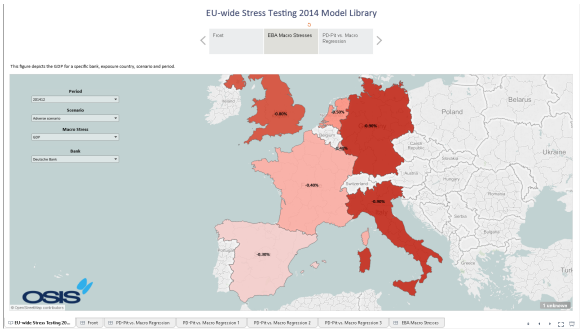

FIGURE 1

These numbers are important to put the results of the stress test into perspective when comparing different banks and credit exposures. Other possibilities are to view HPI, change in unemployment, unemployment, stressed loan to value and real interest rate for a specific bank, scenario and period for all of their exposure classes.

4. UNIVARIATE REGRESSIONS: PD-PIT VS. MACRO

This analysis contains two types of univariate least square regressions between bank specific PD-Pits and various macro stresses. The user can filter on country of bank, countries of exposure, bank and credit exposure. Secondly the user can choose to view certain subsets of these filters such as "show only banks in: Home-country", which implies that it run the model on e.g. Deutsche Bank only in Germany and not for other exposure countries. Thus if we wish to estimate the relation between the stressed loan to value and PD-Pits in a linear regression (see 2.3.1) for all German banks in Germany we (could) set the following filters:

1. Country of bank: *Germany*
2. Bank: *All*
3. Show only banks in: *Home-country*
4. Country of exposure: *All (or Germany)*
5. Probability of Default: *Linear Model*
6. Macro stress: *Change in unemployment*
7. Exposure: *Retail – secured real estate property*
8. Balance Sheet Assumption: *All*
9. Significance Level: *20%*
10. Significance Filter: *All*

and obtain the following analysis depicted in Figure 2.

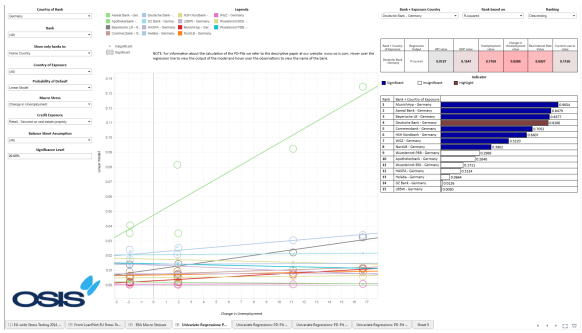

FIGURE 2

Regression coefficients and p-values are revealed by hovering over individual trend lines. In addition, the right-hand side of the workbook summarizes the regression results for Deutsche Bank (highlighted bank) for all macro stresses and ranks all the banks based on a particular macro stress to compare bank specific sensitivities for change in unemployment (or other macro stresses) on a specific credit exposure. In this case the R^2 of the regression between PD-Pit and change in unemployment is able to explain almost 83% of the variation in the Deutsche Bank case, which rank them on the 4^{th} place. The R^2 of the PD-Pits in combination with real interest rate is also visible (69%) in the upper right corner. The same exercise can be conducted for the probit transformation (see 2.3.2) by changing the filter Model equal to *Probit Model.*

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